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March 15, 1832.

JOHN WILLIAM LUBBOCK, Esq. M.A., V.P. and Treasurer, in the Chair.

A Paper was read, entitled "Further Notice of the new Volcano in the Mediterranean." By John Davy, M.D. F.R.S. Assistant Inspector of Army Hospitals.

The author states that since the 25th of October, the date of his last communication to the Society, the crater of the volcano has undergone several changes of form, and has now entirely disappeared. He infers from the phænomena observed, that the crater was one of *eruption*, composed entirely of loose materials, thrown up by volcanic action, and not one of *elevation*, that is, formed of rock which once composed the bed of the sea. In July the heat at Malta was very close and oppressive, the thermometer rising more than once to 105° of Fahrenheit, and the western sky had a dark lurid red hue: but these atmospheric states are regarded by the author as independent of the volcano, for the temperature of the air in its immediate vicinity was very little affected by it.

A Paper was also read, entitled "A method of deducing the Longitude from the Moon's Right Ascension." By Thos. Kerigan, R.N. Communicated by Admiral Sir Edward Codrington, F.R.S.

The author has recourse to the moon's right ascension as an element for determining the true meridian of the place of observation: his method being an extension of that given by him in the first volume of his "Mathematical and General Navigation Tables." He gives examples of the application of this method, and considers that with the aid of a chronometer showing the approximate mean time at Greenwich, the longitude of any given place may be determined, either at sea or on land, within very narrow limits of error, and with much greater practical convenience than by the ordinary method of lunar distances.

March 22, 1832.

The Rev. WILLIAM BUCKLAND, D.D. Vice President, in the Chair.

The reading of a Paper, entitled "An Account of some experiments and observations on the Torpedo," by John Davy, M.D. F.R.S. Assistant Inspector of Army Hospitals,—was commenced.

March 29, 1832.

GEORGE RENNIE, Esq. Vice President, in the Chair.

The following Report, drawn up by the Rev. William Whewell, M.A. F.R.S., and John William Lubbock, Esq. M.A. V.P. and Treasurer R.S., on Professor Airy's Paper, read before the Royal Society on November 24, 1831, and entitled, "On an Inequality of Long Period in the Motions of the Earth and Venus," was read.

Report.

The object of this memoir is similar to that of Laplace's celebrated investigation of the great inequality of Jupiter and Saturn, announced in the Memoirs of the Academy of Sciences for 1784, and given in the volume for the succeeding year. The occasion of that investigation was an acceleration of the mean motion of Jupiter and a retardation of that of Saturn,—which inequalities in the motions of the two planets Halley had discovered by a comparison of ancient and modern observations: and Laplace showed, in the Memoirs just referred to, that inequalities like those thus noticed would arise from the action of gravitation; that they would reach a considerable amount in consequence of twice the mean motion of Jupiter being very nearly equal to five times the mean motion of Saturn; and that their period would be nearly 900 years. The occasion of the investigation of Professor Airy was an inequality in the sun's actual motion, as compared with Delambre's Solar Tables, which appeared to result from a comparison of late observations with those of the last century,—as Professor Airy has explained in a memoir published in the Philosophical Transactions for 1828. This comparison having convinced him of the necessity of seeking for some inequality of long period in the earth's motion, it was soon perceived that such an inequality would arise from the circumstance that 8 times the mean motion of Venus is very nearly equal to 13 times the mean motion of the earth. The difference is 1,675 centesimal degrees in a year, —from which it follows, that if any such inequality exist, its period will be about 240 years.

To determine whether such an inequality arising from the action of gravitation, amounts to an appreciable magnitude, is a problem of great complexity and great labour. The coefficient of the term will be of the order 13 *minus* 8, or 5, when expressed in terms of the excentricities of the orbits of the Earth and Venus, and their mutual inclination; all which quantities are small; and the result would therefore, on this account, be very minute. But in the integrations by which the inequality is found, the small fraction expressing the difference of the mean motions of the planets enters twice as a divisor; and by the augmentation arising from this and other parts of the process, the term receives a multiplier of about 2,200,000. In the corresponding step of the investigation of the great inequality of

Jupiter and Saturn, it was only necessary to take terms of the 3rd order of smallness, and the multiplier by which the terms are augmented has 30^2 instead of 240^2 for its factor.

In the present state of physical astronomy methods exist by which the results of the law of universal gravitation in the planetary system may be obtained to any degree of accuracy, by calculating in succession the terms of successive orders of minuteness, the order being estimated according to the powers and products of the excentricities of the orbits. But it is well known, that in the actual application of these methods, the number of the terms arising from the combination of the several series which occur, and the complexity of the operations by which the coefficients of these terms are to be deduced, increase so rapidly in passing beyond the lower orders of inequalities, that the calculation is difficult and laborious.

The numerical calculation of a perturbation depending on the 5th powers of the excentricities has not been executed, so far as we are aware, except in the case of the great inequality of Jupiter and Saturn, where, as Laplace states (*Mécanique Céleste*, p. ii. liv. 6. 9°), this labour, "pénible par son excessive longueur," has been performed by Burckhardt with a scrupulous attention. And no calculation of a new inequality of a high order, requiring to be placed in the planetary tables, with a new argument, has been published since that of the great inequality by Laplace in 1784.

One of the main parts of the labour of such calculations consists in obtaining the successive terms of a certain quantity on which the perturbing forces depend, and which in the *Mécanique Céleste* is called R. This quantity is a function of the positions of the two planets which affect each other, and involves the reciprocal of the distance of the two bodies. It is to be expanded according to the powers and products of the excentricities and inclination of the two orbits, its successive terms having as factors the cosines of certain angles, all of which increase proportionally to the time.

It may be expanded by Taylor's theorem applied to several variables, according to powers of the excentricities, and f^2, f being the sine of half the inclination*.

In this expansion the coefficients of the cosines of the different arguments are functions of certain quantities A or b (according to the notation of the *Mécanique Céleste*), and of the partial differential coefficients of these quantities with regard to a and a', the radii of the orbits; admitting however of reduction so as to contain the differential coefficients with regard to one of these quantities only.

The quantity b is a function of $\frac{a'}{a}$, and has several values distinguished by different indices: these are connected by certain well-known equations of condition. The author of the present memoir obtains the development of R in terms of quantities C, sym-

* Laplace uses s, the tangent of the inclination. Burckhardt expresses himself to be in great doubt what function of the angle it is best to take.

metrical functions of a and a'; and the different quantities C are of course connected by equations of condition similar to the others.

The general development of R, given in the third volume of the *Mécanique Céleste*, extends only to the terms depending on the squares of the excentricities. Burckhardt carried the development much further in the *Mémoires de l'Institut* for 1808; but Professor Airy's formulæ are not immediately comparable with his, on account of the employment of C instead of b. The formulæ of Burckhardt include however only 6 out of 12 of Professor Airy's coefficients, in consequence of the omission of terms depending on the inclination, by the former mathematician.

In the expansion of R, the terms which proceed according to the powers of the excentricities and of the sine of half the inclination (e, e', f), involve cosines of the multiples of V, T, and $V-T$, (V and T indicating the mean motions of Venus and the Earth with the addition of certain constant quantities.) By expanding also the variations of the radii vectores, which occur in these terms, according to powers of e, e', the cosines of multiples of the arcs V and T again enter these terms. Hence the series will finally contain the products of the cosines of the three kinds of arcs, namely, multiples of $V-T$, V and T; which, as is well known, may be expressed in terms of the cosines of their sums and differences. These last arcs will produce various combinations of the form $pV-qT$. Of these we are to select those in which the arc is $13V-8T$; for such terms will, in the calculation of the perturbations, be divided by very small quantities (namely, either $\frac{1}{240}$ or $\frac{1}{240^2}$), and may thus produce results of appreciable magnitude.

It may serve to assist us in forming a judgement concerning the place of Professor Airy's memoir among the laborious calculations of physical astronomy, if we compare it with the investigation of the great inequality of Jupiter and Saturn, as originally given by Laplace (*Mém. Acad.* 1785), the undertaking to which it has the closest analogy among such researches*.

The number of terms arising from the combination of the three arcs above mentioned, $V-T$, V, and T, which give $13T-8V$, is considerable; but many of them are rejected on account of their coefficients going beyond the 5th order. The following *six* are retained and have their value calculated: those in which $V-T$, V, T are respectively 8, 5, 0; 9, 4, 1; 10, 3, 2; 11, 2, 3; 12, 1, 4; 13, 0, 5. In the Jovi-Saturnian inequality, if V and T still refer to the mean motions of the exterior and interior planets, *four* combinations are taken, namely, those in which $V-T$, V, T are respectively 2, 3, 0; 3, 2, 1; 4, 1, 2; 5, 0, 3.

The number of terms of the calculation depends also upon the

* The comparison is here made with the investigation of the *principal term* only of the Jovi-Saturnian inequality, as the most celebrated and most analogous, not as the most laborious or most recent, of similar investigations.

order to which it is carried. In Professor Airy's investigation there are, to each angular factor, *twelve* terms arising from the combinations of e, e', f; in that of the inequality of Jupiter to the 3rd order, there are *four* such terms.

The number of the coefficients C, of the series for R, which it is requisite to calculate, depends both upon the number of effective combinations of arcs and the number of effective combinations of e, e', f. Hence the number of such coefficients, and their differentials, which Professor Airy's calculation demands, is very considerable. In the calculation for Jupiter, Laplace uses 6 coefficients b, and 14 of their differentials, in which however 28 differentials are virtually obtained. Professor Airy has occasion to use 70 values of C, the corresponding quantity in his process, and 98 of its differential coefficients; these quantities being calculated to a number of places from 7 downwards.

The calculation of the inequalities of the motions of Venus and the Earth, from the numbers thus obtained, requires the combination of these numbers with others depending on the excentricities, inclination, perihelia, and nodes of the orbits; and contains, as has already been said, 12 compound terms in the present investigation, and 4 in that of Laplace.

The greatest amount of the inequality thus explained by Laplace, was $20'$ for Jupiter and $47'$ for Saturn. The effect of the inequality examined in the memoir before us, would give an error in the geocentric longitude of Venus of between $20''$ and $30''$, if the mean motions of the Earth and Venus were determined, by comparing the observations about Bradley's time with the observations of a few years ago; and if the result were applied to calculate the next transit of Venus (in 1874).

The method adopted by Professor Airy in this investigation offers some peculiarities. There are two principal methods which may be employed in such problems: one is the method of *direct solution*, according to which the equations on which the inequalities depend are solved directly, and the values obtained by the first approximate solutions are substituted in the terms before neglected, in order to obtain a new solution. The other method is that of the *variation of parameters* (developed by Lagrange), according to which the planet, at any moment of time, is conceived to be moving in an ellipse, and the alterations are investigated which the elements of this ellipse must continually undergo, in order that the real motion may result. The former of these methods is the one which has generally been employed in calculating all inequalities of the planets except secular ones, and is used by Laplace in the theory of Jupiter and Saturn. In the present memoir the author has adopted the method of the variation of parameters, and he states his opinion that this, or some similar method, will ere long be adopted in the planetary theories, to the exclusion of other methods.

In one instance the author has introduced an alteration into the formulæ given for the variation of the elements by those who have

hitherto employed the theory of Lagrange. The differential $\frac{dR}{de}$, in Lagrange's method, implicitly includes the differential of R with regard to the mean motion. But it has been shown by Lagrange himself, and since him by others, that we may finally omit the term depending on the variation of n, if we use $\int n\,dt$ throughout instead of $n\,t$. This reduction Professor Airy does not adopt, retaining explicitly the term $\frac{dR}{dn}$.

This difference in the formulæ is equivalent to a change in the meaning of the term *epoch*. In determining the longitude of the epoch of the instantaneous ellipse, Laplace, and others who have followed Lagrange, fix it by supposing this longitude to be the angle which we must add to the angle described by the *variable* elliptical mean motion since the origin of the time, in order to have the mean anomaly in the ellipse. Professor Airy assumes the longitude of the epoch to be that angle, which we must add to the angle described by the instantaneous elliptical mean motion, considered *constant* since the origin of the time, in order to have the mean anomaly: the mean motion from the perihelion is, on the first supposition, $\int n\,dt+\varepsilon$, on the second, $n\,t+\varepsilon$. In the results of the calculations in these two ways there is no discrepancy, the difference of the formulæ and the difference of the suppositions necessarily balancing each other.

It may be observed, that according to the method of the variation of parameters, a large portion of the inequality, in the present instance, falls upon the longitude of the epoch. The coefficient of this inequality is something more than $2''$; which produces nearly the same maximum amount in the longitude of the planet, the effects of the variations of the other elements being insensible.

In investigations of such extent and complexity as the one now before us, the selection of notation is a matter of considerable importance, in order to obtain the greatest possible degree of clearness and brevity. In all cases when nothing is gained by the change, it is convenient to the reader that the notation should conform to the best established works already published. Professor Airy has in general used the notation of the *Mécanique Céleste*. He has, however, introduced a new notation, in order to express in an abbreviated manner the differentials of the quantities C, taken m times with regard to one major semiaxis, and n times with regard to the other, and multiplied respectively by the mth and nth powers of these semiaxes; these products occurring so frequently, that the adoption of a short symbol for them, $(m, n)\,C$, saves a great quantity of very repulsive labour.

Another abbreviation employed by Professor Airy respects the angles. In the development of the terms arising from the successive steps of the expansion of R, we obtain terms such as $e^2 \cos 2V$ and $e'^3 \cos 3T$, multiplied by others, such as $\cos(11V - 11T)$; and by the resolution of such products we obtain the cosines of the sums and differences of these angles. But it appears that the sums

alone are useful. Hence it follows, that if we have, at a certain step of the process, $\cos(2V + 3T)$, its coefficient must be $e^2 e'^3$, and this may be written $e^2 e'^3 \cos(2 + 3)$ without fear of mistake; and this, when combined with such a term as $\cos(11V - 11T)$, will produce $e^2 e'^3 \cos(13 - 8)$. This mode of writing and operating is also a great saving of labour; for V and T consist of the mean motions, with several constant terms added or subtracted.

The author states that he has paid great attention to ensuring the accuracy of the work; having gone through the calculation by two different methods, and compared the values thus obtained, both in several intermediate steps, and in the final results.

We regard this paper as the first specific improvement in the solar tables made by an Englishman since the time of Halley, as valuable from the care which the author has employed in the numerical calculations, as well as for the sagacity he has displayed in the detection of an inequality so small, and of so large period; and we recommend its insertion in the Philosophical Transactions.

(Signed) W. Whewell.
J. W. Lubbock.

April 5, 1832.

DAVIES GILBERT, Esq., M.A. Vice-President, in the Chair.

Marshall Hall, M.D., Archibald John Stephens, Esq., Sir William Russell, Bart., M.D., Sir David Barry, Knt., M.D., and Charles Boileau Elliott, Esq., were elected Fellows of this Society.

The following Report, drawn up by Samuel Hunter Christie, Esq., M.A. F.R.S., and John Bostock, M.D. V.P.R.S., on Mr. Faraday's paper, read before the Royal Society on December 15, 1831, and entitled "Experimental Researches in Electricity," was read.

Report.

In the first section of this paper, the author considers the induction of electricity in motion.

Shortly after the discovery by Oersted of the influence of electricity in motion on a magnetic needle, it was almost simultaneously discovered by Arago, Davy, and Seebeck, that iron became magnetic by induction from the connecting wire of a voltaic battery, or the passage of an electric current; but though the effects at first observed were afterwards greatly increased by peculiar arrangements, induction was in all cases restricted to iron. Arago's beautiful experiments on magnetic needles vibrating within metallic rings, and on the mutual action of all metals and magnets, when either is in motion, are undoubtedly instances of a peculiar magnetic induction in other metals than iron; but the very doubtful experiment of Ampère can scarcely be adduced as one. The singular results obtained by MM. Marianini, De la Rive, and Von Beek, referred to by our author, are probably due to electric induction. But none of these

can be considered as having originated the discoveries described in the present paper, excepting so far as all new views originate in the contemplation of results previously obtained.

In this section of his paper the author shows that a peculiar state is induced in a copper wire which is in the immediate neighbourhood of another, through which an electric current passes, that is, which forms the connecting wire in a voltaic circuit. This state of the wire was manifested by it's action on a magnetised needle, and by the induction of magnetism in steel wire submitted to its action.

Two copper wires, each more than 200 feet in length, were wound in the same direction round a large block of wood, the coils of the one being interposed between those of the other, and metallic contact everywhere prevented. The ends of one wire were connected with a galvanometer, and with the ends of the other, contact could be made or broken with a battery of one hundred and twenty pairs of plates. On the contact with the battery being made, the needle of the galvanometer was invariably impelled in one direction, and on the interruption of the contact, it was always impelled in the contrary. After the first impulse on the completion of the voltaic circuit, the needle resumed its natural position, no permanent deflection whatever occurring during the time that this circuit remained complete.

On substituting a helix of copper wire formed round a glass tube for the galvanometer; introducing a steel needle; making contact, as before, between the battery and the inducing wire; and then withdrawing the needle, previously to breaking the battery contact, it was found to be magnetised. If the contact was first made; a needle introduced in the tube; the contact broken; the needle on being withdrawn was found to be magnetised to the same degree nearly as the first, but the poles at the corresponding ends were of the contrary kind.

If the circuit between the wire under induction and the galvanometer was not complete when the contact with the battery was made, then no effect on the needle was observable either on completing or again breaking the first circuit. But the battery communication being *first* made, and *then* the wire under induction connected with the helix containing the needle, on interrupting the battery circuit, the needle was magnetised. These last facts, in a theoretical point of view, are most important: they prove that on completion of the voltaic circuit, the state of the wire under induction undergoes a double change, the one momentary, the other permanent so long as the voltaic circuit remains complete, and only exhibiting a momentary action on the interruption of that circuit.

From the experiments detailed in this section, the author concludes, that currents of voltaic electricity produce, by induction, currents (but which are only momentary) parallel to or tending to parallelism with the inducing currents; that the induced current, by the first action of the inducing current, is in the contrary direction to, and by its cessation in the same direction as, that of the inducing current.

The author next introduced iron into his arrangement, by which means a double induction took place, the iron itself becoming magnetic by induction, in the first instance, and electricity being induced in the copper wire from the magnetised iron, in the second. The effects were here of precisely the same character as before, but greatly increased. By this arrangement unequivocal evidence of electricity in the wire under induction was obtained; for not only was the needle in the galvanometer violently affected, but a minute spark could be perceived on using charcoal at the ends of that wire.

On dispensing altogether with the voltaic arrangement, and substituting for the electro-magnet a cylinder of soft iron, rendered magnetic by contact with two bar magnets, or a common cylindrical magnet of steel, similar results were still obtained. The arrangement and the effects were simply these: several helices of copper wire were formed, in the same direction, round a hollow cylinder of pasteboard, metallic contact being prevented between the contiguous coils: of these, either the *alternate ends* were united, to form *one* long helix, or *all* the corresponding ends to form a *compound* helix; and within the pasteboard cylinder, a cylinder of soft iron was introduced: on the ends of this cylinder being brought into contact with the poles of two bar magnets, united at the other ends so as to resemble a horse-shoe magnet, the needle of the galvanometer was impelled in one direction, and on the contact being broken, in the contrary. Similar effects were produced by simply introducing a cylindrical steel magnet into the hollow cylinder over which the copper wire was wound. The effects were strikingly increased, but were still of precisely the same character, when Knight's large compound magnet, belonging to the Royal Society, was substituted for the bar magnets. Here, the mere approximation to the magnet, of the compound helix, whether containing the cylinder of soft iron or not, was sufficient to impel the needle in one direction, and its recess from the magnet, to give a contrary impulse. But even here, the effects were purely impulsive, the needle invariably returning to its undisturbed direction, when the contact was continued.

As in the voltaic arrangement, a small voltaic apparatus, sufficient to deflect the needle of the galvanometer 30° or 40°, being introduced between the galvanometer and the helix under induction, produced no effect on the impulses given to the needle, on making and breaking contact of the iron cylinder with the magnet: nor did the power of this arrangement appear to be affected after making the contact or after breaking it.

Although all attempts to obtain chemical effects or a spark in this case failed, yet we agree with the author that these experiments prove the production of electricity by ordinary magnetism, and think the reasons which he adduces for its want of energy satisfactory*.

* Since this report was written, a brilliant electric spark has been obtained by Mr. Faraday and Mr. Christie with this magnet, by the very means which, at this time, failed, in consequence of two contacts not taking place at the same instant, on which circumstance the success of the experiment appears entirely to depend.

This discovery has therefore supplied the link in the chain of connexion between electricity and magnetism, which has been wanting since Oersted's discovery. That the electricity developed acts in a peculiar manner, so far from diminishing the interest attached to the discovery, adds greatly to its value.

After the detail of these perfectly original and highly interesting experiments, the author considers the peculiar electric state of the wire when subjected either to volta-electric or magneto-electric induction. This state he terms the electro-tonic state.

Unlike the induction from electricity of tension or the ordinary induction from a magnet, this state of the wire is not analogous to that of the inducing wire; for whatever may be the permanent state of the wire under induction while the voltaic circuit is complete, or the magnetic contact is unbroken, so long as either of these continues, there is no evidence of any change having taken place in it, and its change of state is only rendered manifest at the instant of interrupting the circuit or the contact, and at that of again renewing them; impulsive forces being brought into action at either instant, but in contrary directions in the two cases.

The author observes, that this peculiar condition shows no known electrical effects whilst it continues, nor has he yet been able to discover any peculiar powers possessed by matter whilst retained in this state; that no re-action is shown by attractive or repulsive powers; that no retarding or accelerating power is exerted upon electric currents passing through metal in the electro-tonic state, that is, the conducting power is not altered by it; that all metals take on this peculiar state; that the electro-tonic state is altogether the effect of the induction excited, and ceases with the inductive power; that this state appears to be *instantly* assumed, the force brought into action at the instant of its assumption being merely impulsive.

The author considers that the current of electricity which induces the electro-tonic state in a neighbouring wire, probably induces that state also in its own wire, and that this may be the case with fluids and all other conductors; and concludes that if it be so, it must influence voltaic decomposition and the transference of the elements to the poles. Should facts be found to accord with these views, we consider the author fully justified in his anticipations of the importance of his discovery as applicable to the decomposition of matter, and we certainly feel that the discovery could not have been made by any one more likely to decide this question, or more able to avail himself of a new principle of decomposition when discovered.

In the series of actions proceeding from the voltaic battery which this discovery exhibits to us, a very curious succession is observable. Volta-electricity passes along the connecting wire of the battery, electro-magnetism at right angles to it. By this means the cylinder of soft iron, within the helix into which the connecting wire is formed, becomes a magnet. If the poles of the magnet be joined by an iron bar, ordinary magnetism passes along this bar, but magneto-electricity is induced at right angles to it in a helix wound round it. And again, magneto-electricity is propelled along the wire, and magnetism

is induced in a steel bar at right angles. This bar may again induce magneto-electricity in a wire at right angles to it, by which another bar may become magnetic; and so on, showing a repetition of similar powers successively brought into action, but their efficiency at each step greatly diminished.

The effects hitherto described were due to a momentary action: in order to obtain continuous action the author applied the principle of circular motion. For this purpose a thick copper disc was made to revolve near the magnet, so that a portion near its edge passed between the ends of two bars of iron which concentrated and approximated the poles. The edge and a portion round the centre of the disc were well amalgamated: an amalgamated conductor was applied to the edge of the disc near the poles, and with this, one end of the wire of the galvanometer was connected, the other end being connected with the centre of the disc. While the disc revolved, the needle of the galvanometer was permanently deflected at least 45° in one direction; and when the motion of the disc was reversed, the permanent deflection was in the opposite direction.

When the disc revolved horizontally in the direction of the sun's daily motion, the unmarked pole being beneath the disc and the marked pole above, it appeared, by the indications of the galvanometer, that positive electricity was collected at the edge of the disc nearest to the poles: if the marked pole was below and the unmarked pole above, then negative electricity was collected at that part of the disc: and if in either case the direction of the motion was reversed, the nature of the electricity collected at the same place was also reversed.

The experiment being made in a still more simple form, by passing a plate of copper longitudinally between the poles of the magnet, it appeared that positive electricity was collected on one edge of the plate, and negative on the opposite; and if the plate was passed in the contrary direction, then the electricities on the edges were reversed.

When a wire was passed laterally between the poles, similar results were obtained.

The law according to which the electricity excited depends upon the pole of the magnet near which a wire moves, and the direction of its motion, although not so expressed by the author, appears to be this: Let the wire revolve parallel to itself about a bar magnet, so that its centre coincides with any curve;—for example, (in order to mark more readily the points where the direction of the current of electricity changes,) with an ellipse, the major axis of which coincides with the axis of the magnet, and the minor axis passes through its centre; let the wire be inclined at any angle to the plane of the ellipse, which in the first instance we will suppose to be horizontal, and that the marked end of the magnet is pointing north; and let the wire move parallel to itself in the direction of the sun's daily motion; then while the wire revolves from the *western* extremity of the axis minor round the *marked* pole to the *eastern* extremity, the electric current will be from the end of the wire *below* to the end *above* the orbit:

while it is revolving from the *eastern* extremity round the *unmarked* pole to the *western* extremity of the axis minor, the current of electricity will be from the upper to the lower end of the wire; and whatever position the plane in which the wire revolves may take by revolving about the axis of the magnet, or whatever may be the position of this axis, still the current of electricity will be from the end of the wire in the same position, relatively to the plane of revolution, as before. If the direction of the motion be reversed, the direction of the current will likewise be reversed.

It would follow from this, that if two wires parallel to each other, on opposite sides of a bar magnet, and perpendicular to its axis, be moved along the sides of the magnet in the same direction, the currents of electricity in them will be in opposite directions; and hence we may draw this important conclusion,—that there must be some internal arrangement in a magnet, whether of currents or of particles, which renders the same absolute motion, a motion in contrary directions relatively to such arrangement on the opposite sides of the magnet.

From all these experiments the author concludes, that when a piece of metal (and the same may be true of all conducting matter,) is passed either before a single pole, or between the opposite poles of a magnet, electric currents are produced across the metal, transverse to the direction of motion; and which therefore in M. Arago's experiments approximate towards the direction of radii. Assuming the existence of these currents, he satisfactorily accounts for the phænomena observed in these experiments and in those by Mr. Babbage and Sir John Herschel. Thus, the disc revolving in the direction of the sun's daily motion beneath the marked pole of a magnet, currents of positive electricity set from the central part towards the circumference near the pole, and the action of these currents is to move the pole also in the direction of the sun's motion; so that the magnet, if at liberty to revolve, will move in the same direction as the disc.

Electric currents similar to those produced by passing copper between the magnetic poles, were produced by iron, zinc, tin, lead, mercury, and all the metals tried. The carbon deposited in the coal-gas retorts also produced the current, but ordinary charcoal did not; nor could any sensible effects be produced with brine, sulphuric acid, or saline solutions. Although the author succeeded in obtaining a continuous current of electricity by means of the revolving disc, yet he was not able, by this means, to produce any sensation upon the tongue, to heat fine platina wire, to produce a spark with charcoal, to convulse the limbs of a frog, or to produce any chemical effects. That he should have failed in obtaining these most striking effects of electricity, we attribute to the feebleness of the electricity excited, and feel assured that by adopting means greatly to increase the intensity, all these effects will result from the electricity derived from ordinary magnetism.

The facts contained in this paper of Mr. Faraday's, and the con-

clusions which he draws from them are so important, that we feel we should not have done justice to the communication, had we not given an abstract of the whole, at the same time that we stated our opinion of its value. Had the author's discovery consisted alone of the simple fact, that steel may be magnetised by a distant magnet, in a manner similar to that employed with the voltaic battery, we should have considered it of the highest importance in the inquiry concerning the connexion between magnetism and electricity; but when we see permanent effects which, hitherto, have only been derived from electricity, now derived from the common magnet, by calling in the aid of motion, showing clearly that electricity can thus be excited; and find that the laws which govern the phænomena are established, we cannot but entertain hopes that a door has been opened through which may at length be discovered the precise distinction between two agents which in many respects so greatly resemble each other in their effects and in their laws of acting. Such being our opinion of the results obtained by Mr. Faraday, we can have no hesitation in recommending most strongly the publication of his paper in the Transactions of the Royal Society.

(Signed) S. H. Christie.
J. Bostock.

Dr. Davy's Paper on the Torpedo, was then read in continuation.

April 12, 1832.

HIS ROYAL HIGHNESS THE DUKE OF SUSSEX, K.G. President, in the Chair.

The reading of Dr. Davy's Paper, entitled, "An Account of some experiments and observations on the Torpedo," was resumed and concluded.

The late Sir Humphry Davy gave an account, in a paper published in the Philosophical Transactions for 1829, of some experiments which he made on the Torpedo, with the view of ascertaining how far its electricity is analogous to that of the voltaic, or other galvanic batteries; but the results he obtained were altogether of a negative kind. He was prevented by the declining state of his health from prosecuting this inquiry, which he was still ardently bent upon completing, and which he requested his brother would carry on after his death. The author, accordingly, when at Malta, being in a favourable situation for obtaining living torpedos, made the series of experiments which are related in the present paper. They entirely confirm those of Mr. Walsh made in 1772, and which established the resemblance of the agency exerted by this fish to common electricity; and they also prove that, like voltaic electricity, it has the power of giving magnetic polarity to steel, of deflecting the magnetic needle, and also of effecting certain chemical changes in fluids subjected to its action. Needles perfectly free from magnetism were introduced within a spiral coil of copper wire, containing about 180 convolutions; the whole coil being an inch and a half long and one

tenth of an inch in diameter, weighing only four grains and a half, and being contained in a glass tube just large enough to receive it. On the electric discharges from a vigorous torpedo being made to pass through the wire during a few minutes, the needles were rendered strongly magnetic. The same influence transmitted through the wires of the multiplier produced very decided deflexion of the needle; the under surface of the electrical organ of the torpedo corresponding in its effect to the zinc plate of the simple voltaic circle, and the upper surface corresponding to the copper plate. No effect of ignition could be perceived when the discharge from the torpedo was made to pass through a silver wire one thousandth of an inch in diameter: nor could unequivocal evidence be obtained of the production of sparks on interrupting the circuit; the slight luminous appearances which occurred being probably of the same kind as those often exhibited by sea water when agitated. A small gold chain, however, composed of sixty double links, was found to be capable of transmitting the shock; a fact which seems to show that air is not impermeable to the electricity of the torpedo. When fine silver wires, interrupted by a solution of common salt, were placed in the circuit, minute bubbles of air collected round the point communicating with the under side of the torpedo, but none at the other point. When gold wires, instead of the silver ones, were used, gas was evolved from each of the extremities; but in greatest quantity, and in smaller bubbles, from the lower, than from the upper wire. With a strong solution of nitrate of silver, the point of the lower gold wire became black, and only two or three bubbles arose from it; the point of the upper gold wire remaining bright, and being surrounded with many bubbles. Similar, but less distinct, results were obtained by employing a strong solution of superacetate of lead.

The remainder of the paper is occupied with a detailed account of the anatomical structure of the electrical organs of the torpedo, and of the muscles that surround them. The texture of the columnar portions of those organs appears to be homogeneous, with the exception of a few fibres, probably branches of nerves, which pass into them. A large quantity of water, separable by evaporation, enters into their composition: and they undergo spontaneous changes more slowly than the muscles. They are incapable of contraction by any of the ordinary stimuli, and even that of an electric shock from a voltaic battery, applied either to the organs themselves or to the nerves which supply them. Hence the conclusion is drawn that these organs are not muscular, but that their columns are formed by tendinous and nervous fibres, distended by a thin gelatinous fluid.

The anatomical account is concluded by a description of the origin, course, and distribution of the nerves belonging to the electrical organs. The author found that the gastric nerves are derived from these; and hazards the conjecture that superfluous electricity may, when not required for the defence of the animal, be directed to the stomach, so as to promote digestion: in corroboration of which he cites the instance of a torpedo which, when living, had

been frequently excited to give shocks, and in whom a small fish found in its stomach after death, appeared to be totally undigested. The secretion of mucus was also either suppressed or considerably diminished. From the circumstance that the branchiæ are supplied with twigs of the electrical nerves, the author conceives there may be some connexion between the electrical and the respiratory functions; and that the evolved electricity may be employed in decomposing water, and in thus supplying the system with air, in situations where the animal has not access to that of the atmosphere. The author considers the mucous system of the torpedo as performing important offices in its economy, in consequence of its connexions with the electrical nerves. Contrary to the statement of Mr. Hunter, he finds that the electrical organs are very scantily supplied with blood-vessels. He concludes by some remarks on the peculiar characters of the electricity of the Torpedo, the purposes it appears to serve, and the varieties exhibited by different individuals, according to the age, the sex, and other circumstances.

The Meetings of the Society were then adjourned over Easter to the third of May.

May 3, 1832.

JOHN BOSTOCK, M.D. Vice President, in the Chair.

The following Report, drawn up by the Rev. William Whewell, M.A. F.R.S., the Rev. George Peacock, M.A. F.R.S., and the Rev. Henry Coddington, M.A. F.R.S., on Mr. Lubbock's Paper, read before the Royal Society Feb. 9, 1832, and entitled, "Researches in Physical Astronomy," was read.

Report.

The method of the variation of parameters as applied to the investigation of the perturbations of the solar system has been successively developed in modern times. This method gives the variations of the elements of the elliptical orbit in terms of the differentials of a certain function R of these elements, and of the disturbing forces. Euler, Lagrange (1783), Lagrange and Laplace (1808) obtained the formulæ for $d\alpha$, de, $d\varpi$, dp, dq where $p = \tan\phi \sin\theta$, $q = \tan\phi \sin\theta$. Poisson first gave the expression for $d\varepsilon$. Pontécoulant, p. 330, has introduced $d\iota$ and $d\nu$ instead of dp and dq; but those developments gave expressions neglecting the square of the disturbing force. Mr. Lubbock has published (in a Paper in the Phil. Trans. April 1830,) expressions which include the effect of any power of the disturbing force. This method has been principally applied to the secular inequalities; but it is susceptible of being applied with no less strictness to periodical inequalities, all of which may be represented by certain changes in the elements of the elliptical orbit.

But the same problems may also be approximately solved directly; for we obtain a differential equation involving the radius vector and the time. In this equation there occurs the same func-

tion R of which we have already spoken; and this function is expanded according to terms involving cosines of the mean motions of the disturbing and disturbed planet, and cosines of the difference of certain multiples of these motions. This expression has been treated of by various authors, and among others Mr. Lubbock has himself (in memoirs read May 19 and June 9, 1831,) given the expansion of R in a form suited to his present object.

The co-efficients of the terms in this expansion are arranged, as usual, according to the order of the excentricities, their powers and products, and to the power of the $\sin^2$ of half the inclination. These coefficients involve also certain quantities $b_{n,i}$ where n and i have a variety of values; and these quantities depend on the ratio of the mean distances of the disturbing and disturbed bodies from the sun.

Solving the differential equation which involves r, by the equating of co-efficients, Mr. Lubbock finds a value for the reciprocal of r in such terms as have been mentioned. By certain algebraical transformations of the fractional coefficients in which i occurs, (and by certain equations of condition between $b_{3,i-1}$, $b_{3,i}$, b_{3i+1}, and between similar quantities,) the expression for the reciprocal of r is transformed and reduced, the arcs remaining as they were.

But by the properties of the ellipse, the reciprocal of r is equal to a series of terms involving the excentricities, and involving also cosines of the mean anomaly and its multiples: and hence the variation of this reciprocal is equal to a similar series, involving sines and cosines of such arcs, and involving also the variations of the elliptic elements. By substituting the variations of the elliptic elements given by the formulæ above mentioned, when we put for R its expansion, we have a certain series of sines and cosines with their coefficients multiplied into certain other sines of the same kind.

It is found that the sines and cosines thus multiplied produce, by trigonometrical transformations, arcs identical with those which were found in the value of the reciprocal of r obtained by the former method; and the coefficients are also found to be identical with those resulting from the former transformations and reductions.

We have not thought it necessary to verify the somewhat complex reductions by which Mr. Lubbock has shown the identity of the results obtained by these two methods. The mode of proceeding is perfectly satisfactory, and the truth of the conclusion might have been foreseen. The reductions, however, by which identity was to be exhibited were by no means obvious: and we conceive it not unlikely that the development of them may sometimes be of use in enabling us to judge which of the two methods of solution may be applied with most convenience in particular cases.

We are of opinion that this Paper is well worthy of being printed in our Transactions. (Signed) W. Whewell.
Geo. Peacock.
H. Coddington.